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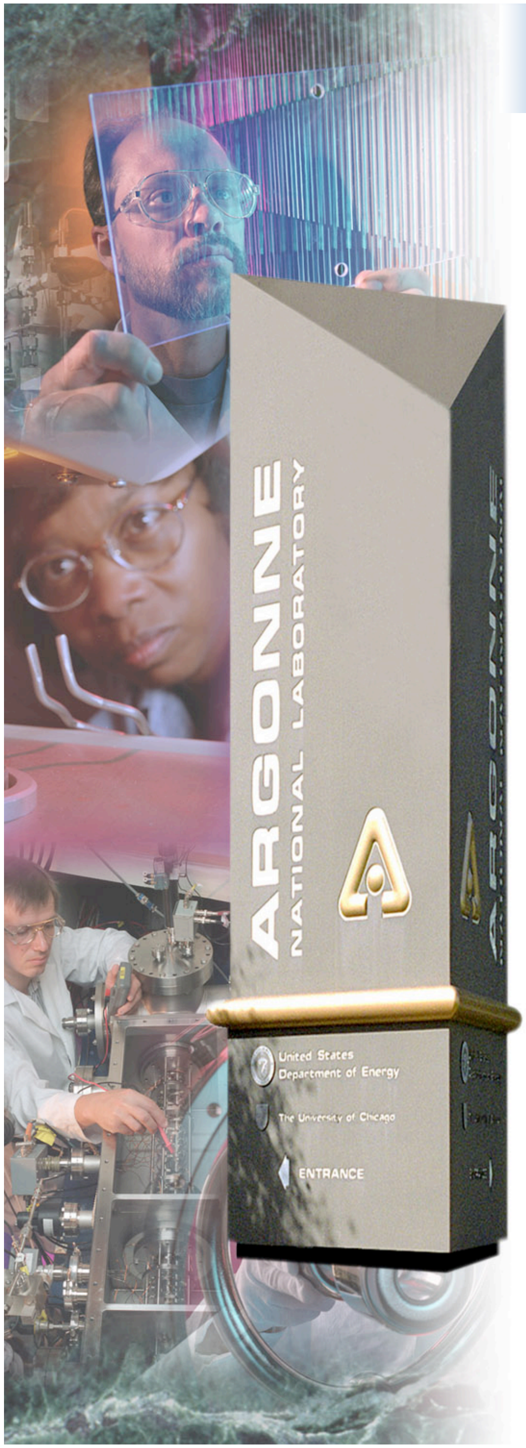

Nuclear Data Sensitivity Analysis

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Introduction

- Last fiscal year work was finalized: uncertainties on several reactors of interest of the AFCI and Gen IV programs were evaluated and target accuracies on cross sections were assessed for satisfying assigned uncertainties on integral parameters
- A three year program that will assess the quality available cross section data files: ENDF/B-VII, JEF3.1 (and possibly JENDL3.3) has been started. This is done by selecting among the several hundreds integral experiments performed in USA and abroad those relevant and representative of the AFCI and Gen IV program systems using covariance data and sensitivity techniques and then analyzing the performance of the data files on the selected systems
- In a first phase experiments carried out at the ZPR and ZPPR facilities are considered. In a second phase the selection will be extended to experiments that are part of the IRPhEP database. After the selection is made, the chosen systems will be analyzed with the most sophisticated methodology and cross section data in order to evaluate their performance

Conclusions from Last Year Work

Data uncertainties, are significant only for a few parameters:

- K_{eff} (for thermal systems, at EOC due to high Burn up)
- Burn up reactivity swing
- Some void coefficients
- At a lesser extent, neutron source (thermal systems)
- Other parameters, within expected target accuracies

Despite a significant MA recycling in fast systems and extended burn-ups in thermal systems, MA data do not play a major role. Some exceptions:

Am-243 capture in fast and thermal range (10 and 20% uncert. respect.)
Am-242m fission in the fast range (10% uncertainty)

As for major actinides U-238 and Pu isotope data uncertainties are very significant:

Pu-239 fission between 1 MeV and 1 keV and below 1 eV
Pu-240 capture at the first resonance
Pu-241 fission between 1MeV and 1 keV
U-238 capture between 0.2MeV and 2keV and between 400eV and 10eV
U-238 inelastic

As for structural/coolant materials:

Fe inelastic (10-20% uncertainty)
Na inelastic (30% uncertainty)
Pb inelastic (40% uncertainty)
Si inelastic (30% uncertainty)

Conclusions from Last Year Work (cont.)

Better and more complete covariance matrices are needed. However:

•The timescale for the production of a full set of covariance matrices should be 2-3 years, to have impact on the feasibility assessment of most concepts and to provide the basis for potential, high priority new cross-section measurements or nuclear data oriented integral experiments.

A target accuracy assessment was performed:

•In many cases very stringent requirements have been obtained (e. g. Pu240 for the VHTR case, U238 inelastic for GFR, etc.) that will be difficult to achieve.

•Integral experiments and statistical data adjustments will likely continue in the future to play a role in assessing the good quality of nuclear data and providing "ad hoc" solutions for reduced margins neutronic designs.

A new WPEC subgroup on "Nuclear Data Needs for Advanced Reactor Systems" has been created (first meeting in May).

The approach and theoretical background

Sensitivity studies, via GPT (Generalized Perturbation Theory), on the selected integral parameters for the different systems under consideration.

Once the sensitivity coefficient matrix S and the covariance matrix *D* are available, the uncertainty on the integral parameter can be evaluated:

$$\ddot{\mathbf{A}}\mathbf{R}_0^2 = \mathbf{S}_{\mathbf{R}}^{+}\mathbf{D}\mathbf{S}_{\mathbf{R}}$$

The representativity factor:

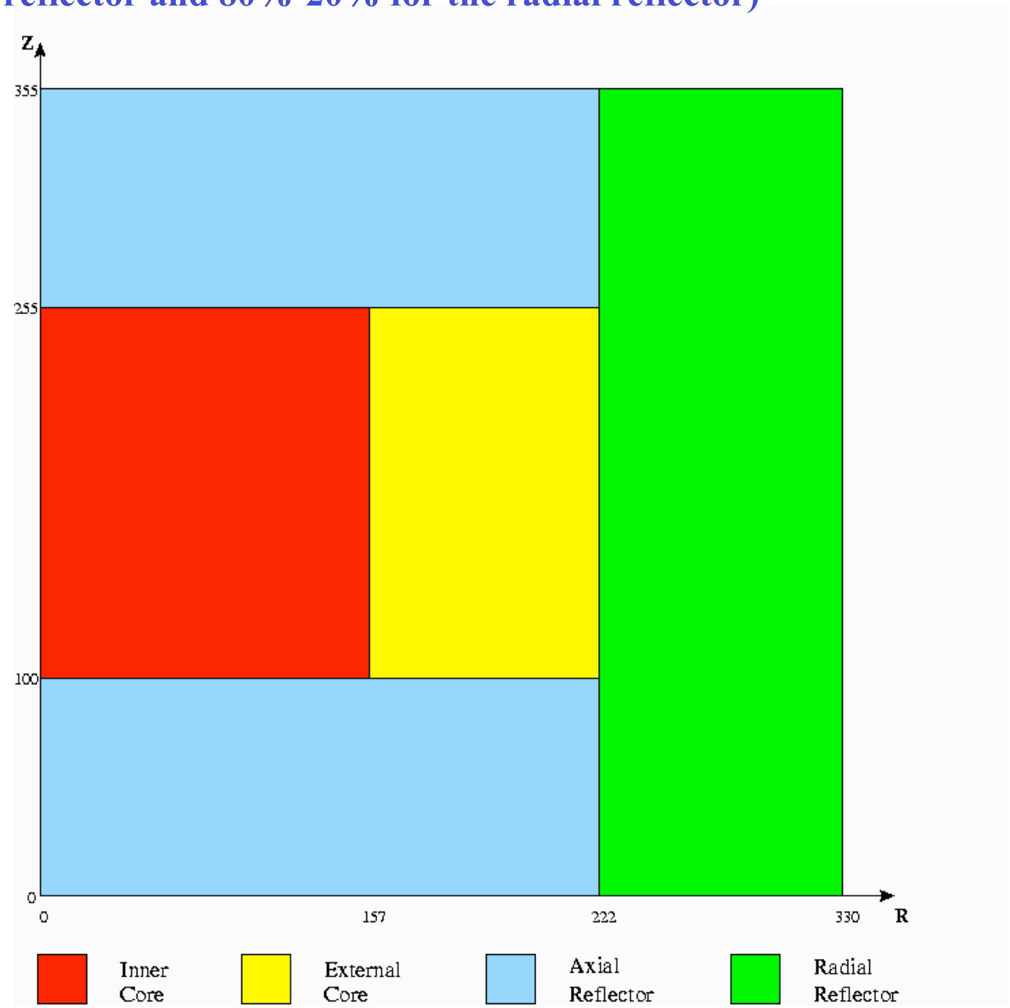
$$\mathbf{r}_{\mathbf{RE}} = \frac{\left(\mathbf{S}_{\mathbf{R}}^{+}\mathbf{D}\mathbf{S}_{\mathbf{E}}\right)}{\left[\left(\mathbf{S}_{\mathbf{R}}^{+}\mathbf{D}\mathbf{S}_{\mathbf{R}}\right)\left(\mathbf{S}_{\mathbf{E}}^{+}\mathbf{D}\mathbf{S}_{\mathbf{E}}\right)\right]^{1/2}}$$

allows to reduce the uncertainty by:

$$\Delta\mathbf{R}_1^2 = \Delta\mathbf{R}_0^2(1-\mathbf{r}_{\mathbf{RE}}^2)$$

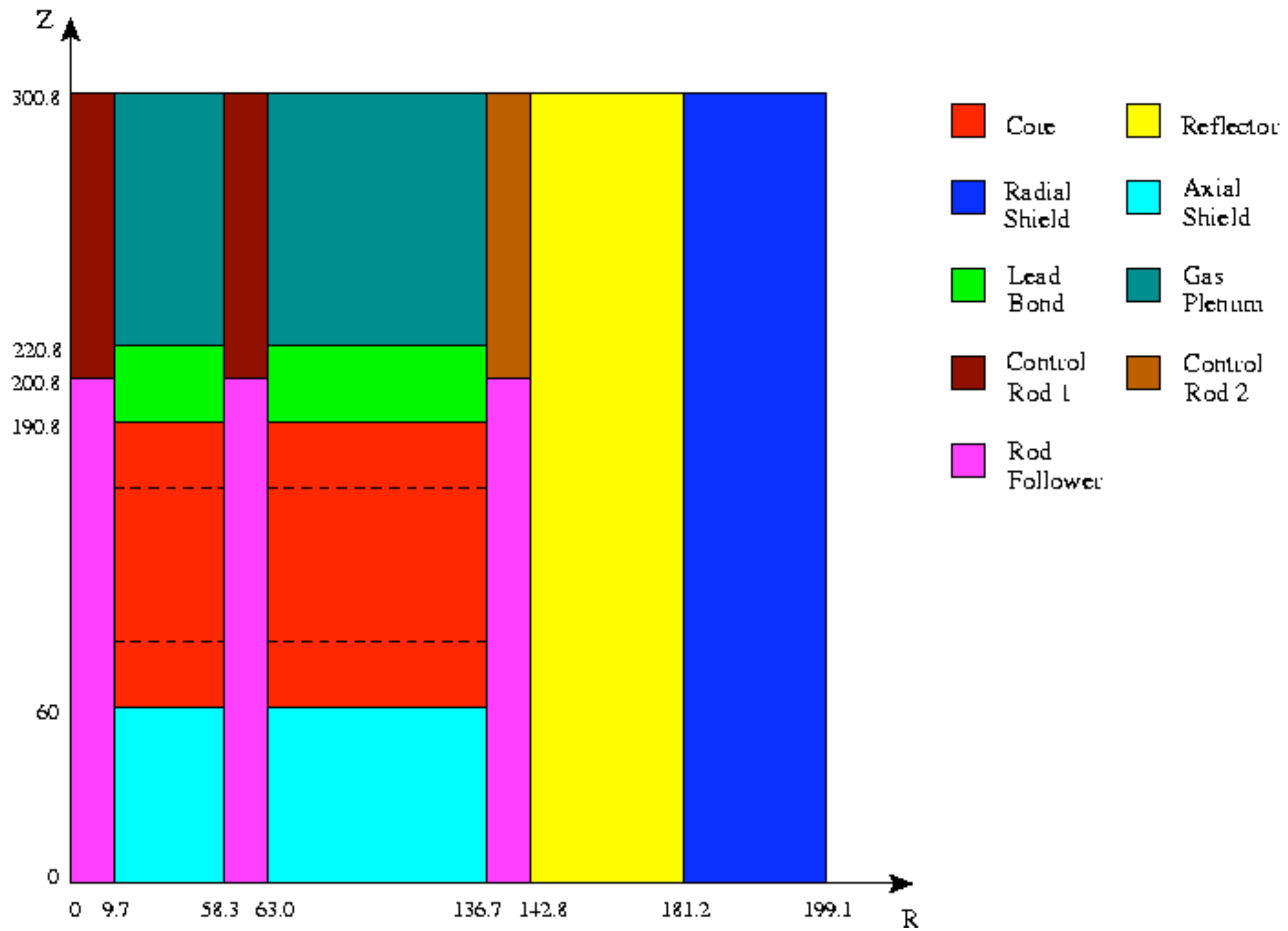
GFR

The gas cooled fast reactor contains CERCER fuel which is a mixture (56%-44%) of a ceramic matrix material SiC and a ceramic heavy metal carbide fuel with 5% of Minor Actinides (MA). The materials of the core region are structure (20%), coolant (40%) and fuel (40%) and the average enrichment (PUC/(UC+PuC)) is 17%. The coolant is helium and the reflector is a mixture of Zr_3Si_2 and coolant (60%-40% for the axial reflector and 80%-20% for the radial reflector)



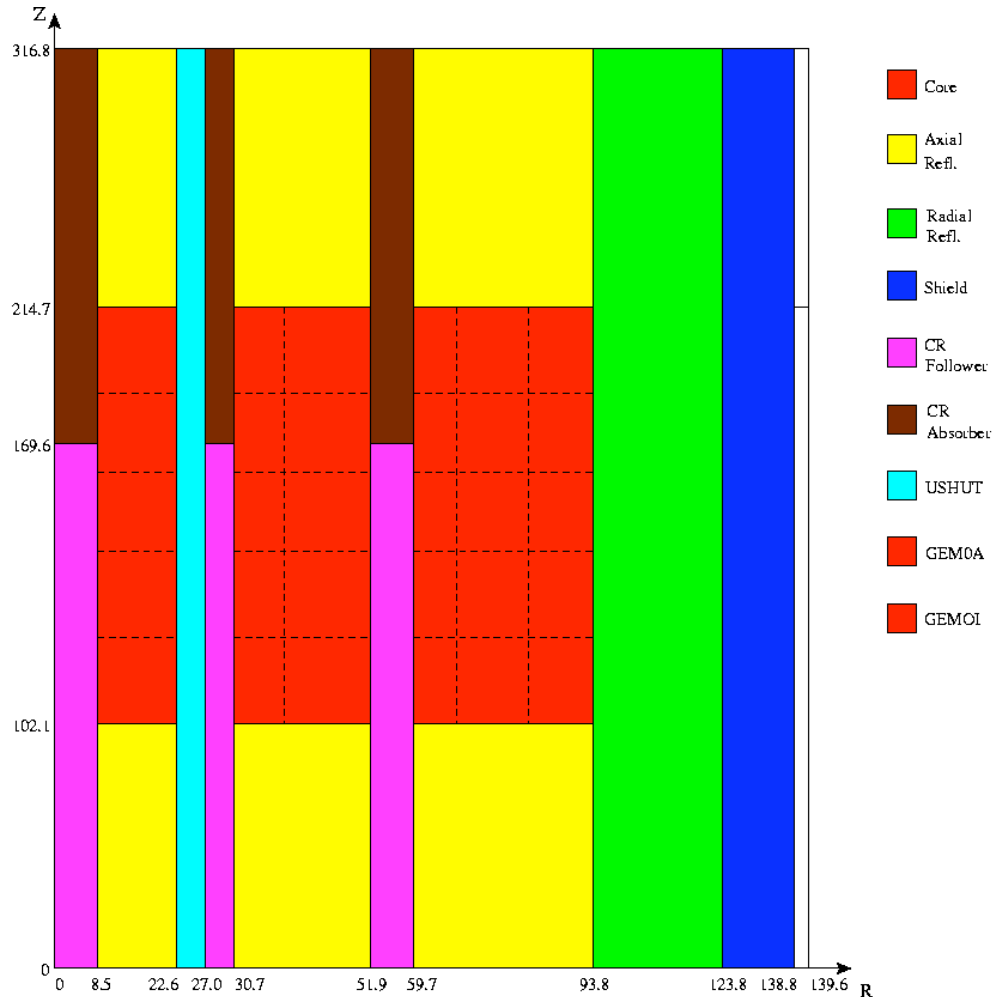
LFR

The lead cooled fast rector, that is being also investigated in the frame of a benchmark problem prepared by KAERI and also adopted by IAEA, is a 900 MWth reactor loaded with U-TRU-Zr metallic alloy fuels (2% of MA). The core contains 192 hexagonal ductless fuel assemblies and it is surrounded by ducted lead reflector and steel shields.



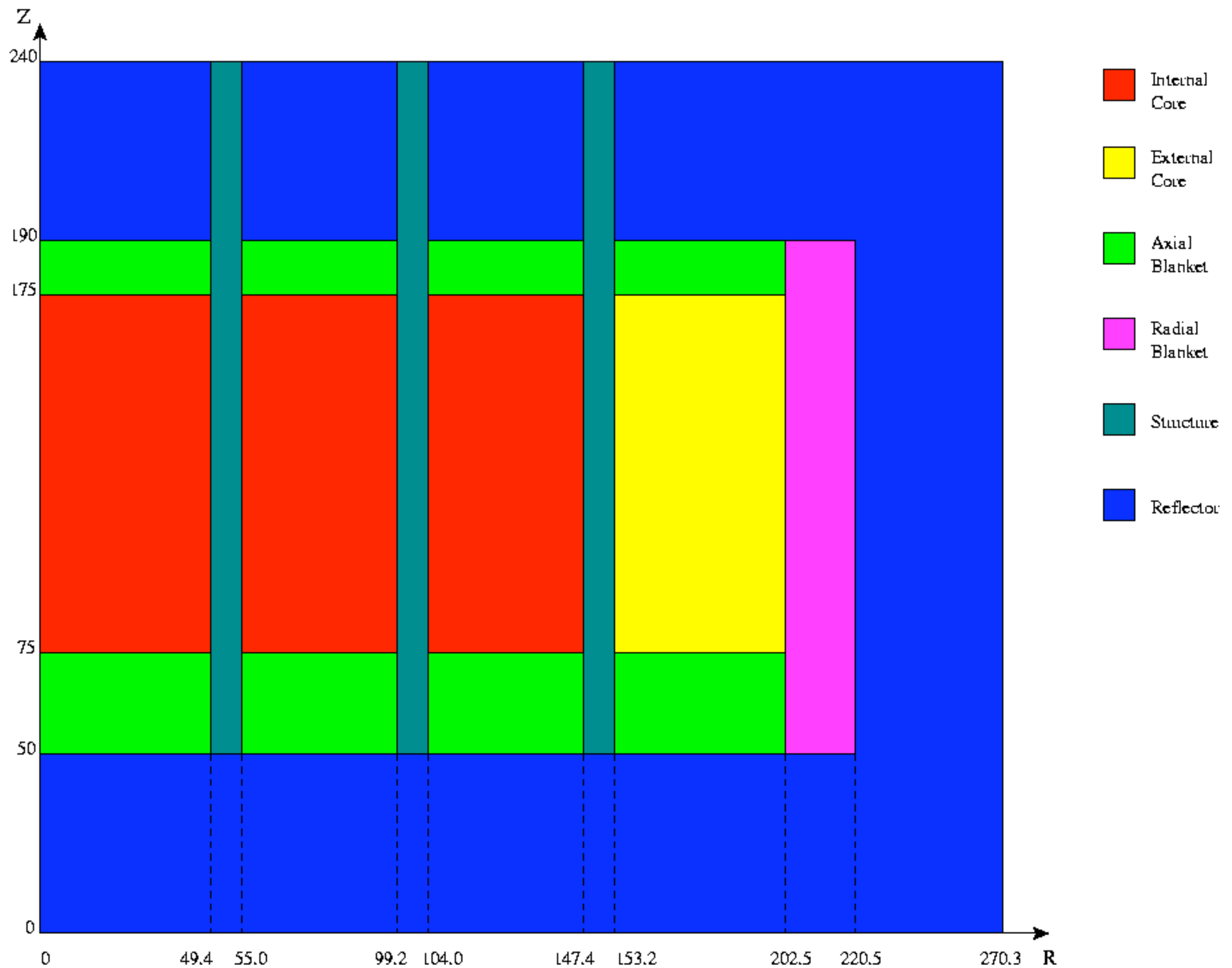
SFR

The small size transmuter sodium cooled fast reactor is an 840 MWth reactor loaded with U-TRU-Zr metallic alloy (10% of MA) and very low conversion ratio (<0.25).



EFR

The large size sodium cooled reactor, whose specifications have been provided by the CEA, is a 3600 MWth reactor loaded with U-TRU oxide fuel (1% of MA). The core is surrounded by a blanket.



Integral Parameters

Sensitivity coefficients are calculated on:

- K_{eff}
- $^{238}U\ \sigma_f\ /^{239}Pu\ \sigma_f$ at core center
- $\eta = \upsilon\Sigma_f/\Sigma_a$ (being representative of the adjoint)
- β_{eff} (if available)
- $^{238}U\ \sigma_f$ slope close to reflector or blanket
- $^{239}Pu\ \sigma_f$ slope close to reflector or blanket
- Control rod reactivity (if available)
- Coolant void reactivity (if available)

Selected Experiments

A first bibliographical search has been done on past ZPR and ZPPR experiments. The first ones selected are:

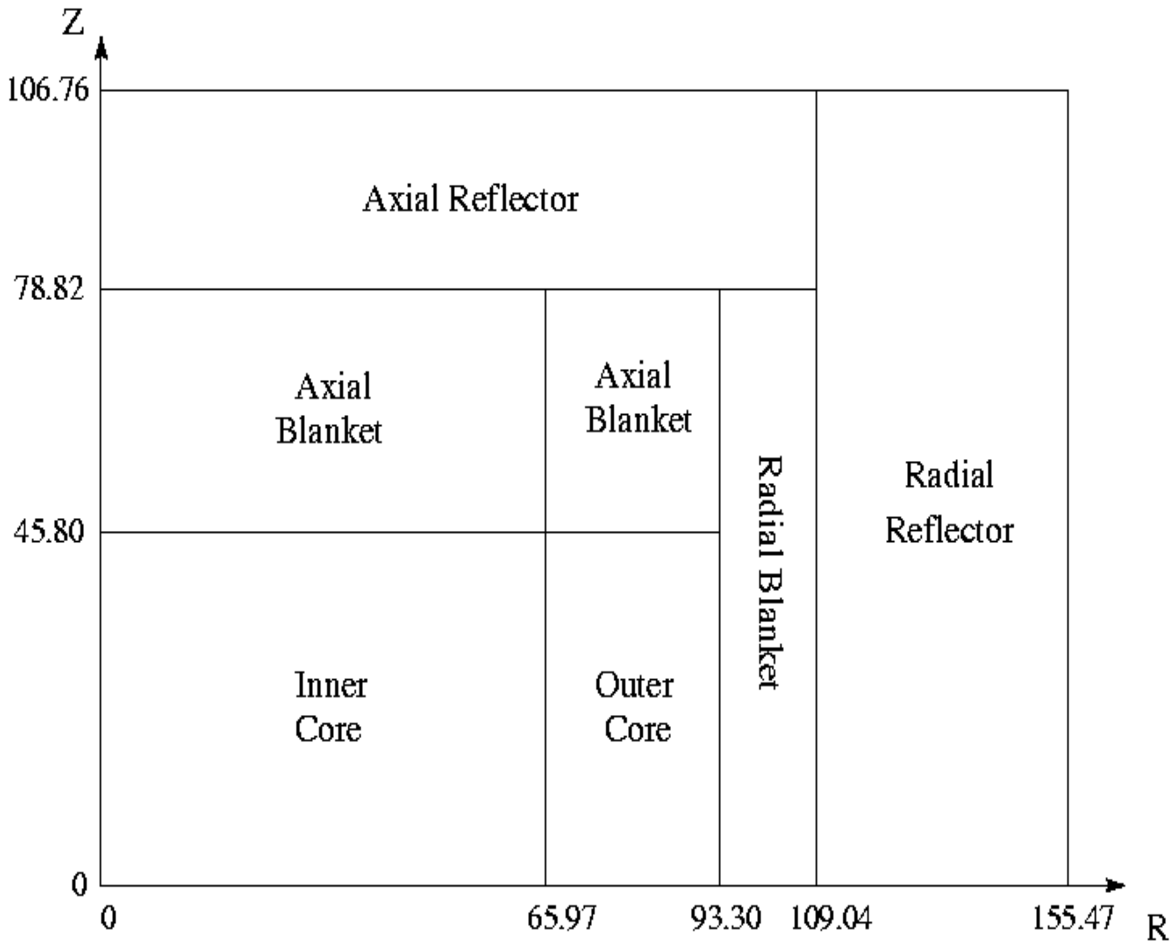
- ZPPR-2, ZPPR-3, ZPPR-9, and ZPPR-10 as representative of large size sodium cooled fast reactor (EFR)
- ZPPR-15 for the small size sodium cooled fast transmuter reactor (SFR)
- ZPR3-48, -53, -54, 55, ZPR9-28, -31 for the gas cooled fast reactor (GCFR)

"Home made" covariance Matrix (ANL)

- We started by updating the covariance matrix used in the ADS study by taking into account the **results of clean integral experiment analysis**, in particular irradiated sample/fuel analysis, which gave valuable information on **capture and some (n,2n) cross-sections, and fission rate measurements in critical assemblies**
- The uncertainty values, are given by **"energy band"**, consistent with multigroup energy structures used for deterministic calculations both of thermal and fast reactors
- **15 energy groups** have been selected between 20 MeV and E(thermal).
- The covariance matrix diagonal values have been estimated on the performance of the most recent data files in the analysis of a large set of integral experiments in different spectra.

ZPPR-15

The ZPPR-15A experiment was performed to support the DOE innovative design initiatives in August 1985. The assembly is based on sodium cooled, metallic fueled, homogeneous, two-enrichment-zone core of about 330MWe size. With respect to the ZPPR-15A, the EFR has a bigger size and an oxide fuel loading; the SFR has a comparable size, metallic fuel, but a larger amount of minor actinides. and. additionally. the SFR has no blanket.



ZPPR-15
Representativity

	R = EFR E = ZPPR-15A	R = SFR E = ZPPR-15A	R = EFR E = ZPPR-15A	R = SFR E = ZPPR-15A
Integral Parameter	$\mathbf{K_{eff}}$	$\mathbf{K_{eff}}$	$\dfrac{\langle \sigma_{f,U8} \Phi \rangle_{pos1}}{\langle \sigma_{f,Pu9} \Phi \rangle_{pos1}}$	$\dfrac{\langle \sigma_{f,U8} \Phi \rangle_{pos1}}{\langle \sigma_{f,Pu9} \Phi \rangle_{pos1}}$
Absolute Value in R:	1.108481	1.052802	0.025	0.025
Absolute Value in E:	.986312	.986312	0.020	0.020
Total Uncertainty in R:	1.02	1.10	4.84	4.75
Total Uncertainty in E:	1.42	1.42	7.36	7.37
Representativity factor:	0.931	0.613	0.235	0.148
Reduced Uncertainty in R:	0.37	0.87	4.71	4.69

ZPPR-15
Representativity

	R = EFR E = ZPPR-15A	R = SFR E = ZPPR-15A	R = EFR E = ZPPR-15A	R = SFR E = ZPPR-15A
Integral Parameter	**Void coefficient** **$(\rho_{void} - \rho_{ref})$**	**Void coefficient** **$(\rho_{void} - \rho_{ref})$**	$\frac{\langle \sigma_{f,U8} \Phi \rangle_{pos2}}{\langle \sigma_{f,U8} \Phi \rangle_{pos3}}$	$\frac{\langle \sigma_{f,U8} \Phi \rangle_{pos2}}{\langle \sigma_{f,U8} \Phi \rangle_{pos3}}$
Absolute Value in R:	1934.5 pcm	1831 pcm	3.139	3.043
Absolute Value in E:	1652.9 pcm	1652.9 pcm	4.196	4.196
Total Uncertainty in R:	8.40	17.75	3.81	5.46
Total Uncertainty in E:	20.43	20.43	4.12	4.12
Representativity factor:	0.685	0.566	0.932	0.928
Reduced Uncertainty in R:	6.12	14.64	1.38	2.03

ZPPR-15
Representativity

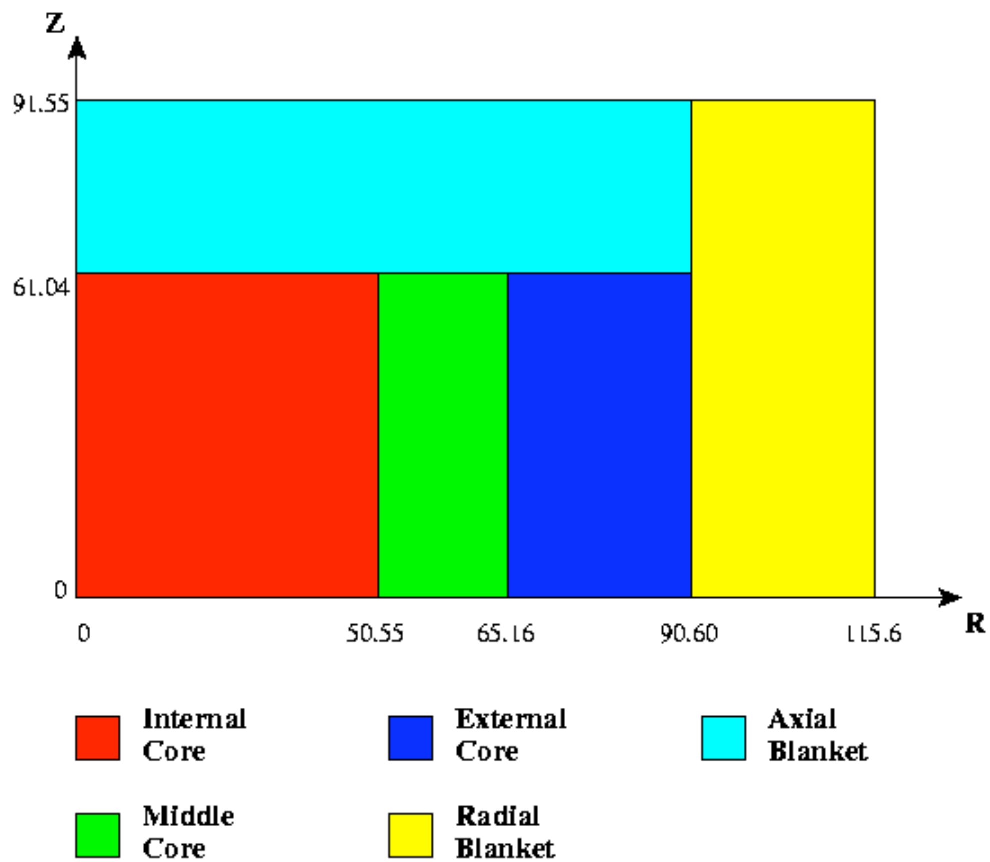
	R = EFR E = ZPPR-15A	R = SFR E = ZPPR-15A	R = EFR E = ZPPR-15A	R = SFR E = ZPPR-15A
Integral Parameter	$\frac{\langle \nu\Sigma_f \Phi \rangle}{\langle \Sigma_a \Phi \rangle}$	$\frac{\langle \nu\Sigma_f \Phi \rangle}{\langle \Sigma_a \Phi \rangle}$	$\frac{\langle \sigma_{f,Pu9} \Phi \rangle_{pos2}}{\langle \sigma_{f,Pu9} \Phi \rangle_{pos3}}$	$\frac{\langle \sigma_{f,Pu9} \Phi \rangle_{pos2}}{\langle \sigma_{f,Pu9} \Phi \rangle_{pos3}}$
Absolute Value in R:	2.94	3.03	0.586	0.045
Absolute Value in E:	2.92	2.92	0.579	0.579
Total Uncertainty in R:	0.04	0.05	1.43	2.59
Total Uncertainty in E:	0.03	0.03	2.02	2.02
Representativity factor:	0.856	0.696	0.836	0.853
Reduced Uncertainty in R:	0.02	0.04	0.78	1.35

ZPPR-15
Representativity

	R = EFR E = ZPPR-15A	R = SFR E = ZPPR-15A
Integral Parameter	β_{eff}	β_{eff}
Absolute Value in R:	206.2 pcm	207.5 pcm
Absolute Value in E:	213.6 pcm	213.6 pcm
Total Uncertainty in R:	0.70	0.64
Total Uncertainty in E:	0.67	0.67
Representativity factor:	0.950	0.593
Reduced Uncertainty in R:	0.22	0.51

ZPR-9

The ZPR-9 Phase I Assembly is the first in a series of critical assemblies designed to provide a reference set of reactor physics measurements in support of a 300MWe GFR Demonstration Plant designed by General Atomic. The Phase I Assembly was the first complete mockup of a GFR core ever built. This assembly was a uniform, single composition core with loading that matched the average enrichment (17.3%) and coolant volume fraction (53%) of the GFR Demonstration Plant. The ZPR-9 Phase I Assembly experiment went critical on April 3, 1975 and the experimental program was completed on June 25, 1975. With respect to the ZPR-9, the GFR core has a bigger size (24000 l compared to 3140 l), but has no blanket. The GFR has a 5% minor actinides loading, while the ZPR-9 contains no minor actinides



ZPR-9 Representativity

	R = GFR E = ZPR-9	R = GFR E = ZPR-9	R = GFR E = ZPR-9
Integral Parameter	K_{eff}	β_{eff}	$\frac{\langle \sigma_{f,U8}\Phi \rangle_{pos2}}{\langle \sigma_{f,U8}\Phi \rangle_{pos3}}$
Absolute Value in R:	1.01045	191 pcm	2.061
Absolute Value in E:	0.99749	222 pcm	2.125
Total Uncertainty in R:	1.20	0.90	1.98
Total Uncertainty in E:	1.24	0.58	2.19
Representativity factor:	0.693	0.677	0.146
Reduced Uncertainty in R:	0.86	0.66	1.96
Integral Parameter	$\frac{\langle \nu\Sigma_f \Phi \rangle}{\langle \Sigma_a \Phi \rangle}$	$\frac{\langle \sigma_{f,U8}\Phi \rangle_{pos1}}{\langle \sigma_{f,Pu9}\Phi \rangle_{pos1}}$	$\frac{\langle \sigma_{f,Pu9}\Phi \rangle_{pos2}}{\langle \sigma_{f,Pu9}\Phi \rangle_{pos3}}$
Absolute Value in R:	2.94	0.028	0.777
Absolute Value in E:	2.93	0.030	1.353
Total Uncertainty in R:	0.05	7.58	3.12
Total Uncertainty in E:	0.02	6.59	0.41
Representativity factor:	0.653	0.914	0.08
Reduced Uncertainty in R:	0.04	3.08	3.11

Conclusions

- Work has started on selecting representative experiments from the ZPR and ZPPR series. Integral parameters of interest have been defined and an initial set of experiments have been selected.
- A first set of representativity calculations has been performed for the ZPPR-15 and ZPR-9 configurations with respect of the EFR, SFR, and GFR reactors. Only for a few parameters the representativity is significant.
- Work will continue on new experimental configurations. Detailed analysis of experimental results will then follow in order to quantify the performance of cross section data libraries.
- The exchange of experimental results of the CIRANO experimental campaign against the ZPR3 -53, -54 has been finally approved and data will become available. The analysis of these experiments will be of definite help for characterizing the reflector effects and useful for identifying the related data problems (if any).